Repute

Version 1.5

User Manual

PILE GROUP DESIGN

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Chapter 1
Introducing Repute

Repute™ is a computer program for determining the response of pile groups to 3-dimensional loading, using linear or non-linear soil models. Repute features:

- a notebook style user interface for easy entry of your pile, layer, and loading data
- a lightning-fast calculation engine based on the boundary-element method
- extensive reporting capabilities via its in-built web browser, rich text viewer, and graph control

Repute's calculation engine is the leading-edge program PGroupN (used under exclusive licence from Geomarc), which provides a complete 3D non-linear boundary element solution of the soil continuum. This overcomes limitations of traditional interaction-factor methods and gives more realistic predictions of deformations and the load distribution between piles.

Repute is the first pile-group design program to deal efficiently with soil non-linearity, avoiding exaggerated stresses and consequential high loads and bending moments at pile-group corners (a common limitation of linear-elastic models). Benefits of this include greatly improved designs and significant savings in construction costs.

Repute is supplied with a detailed *User Manual* (this book), including three step-by-step tutorials. A separate chapter explains the background theory and assumptions behind the program. Technical support for Repute is provided free-of-charge for 30 days and thereafter via an annual support agreement. Service Packs are placed on the Geocentrix website (www.geocentrix.co.uk/support) at regular intervals.

About this manual

The *Repute User Manual* (this book) explains how to install and use Repute. It includes an overview of the program, three step-by-step tutorials, and a separate chapter giving background theory and assumptions behind the program.

The latest version of this manual (including any corrections and/or additions since the program's first release) is available in electronic (Adobe® Acrobat®) format from the Geocentrix website. Please visit www.geocentrix.co.uk/repute and follow the links to Repute's support pages.

Other sources of information

Windows documentation and online help

This manual assumes that you are familiar with Microsoft® Windows® operating systems, Windows 95/98/Me or Windows NT4/2000/XP. If not, please refer to your Windows documentation and online help for assistance.

Reference manual

The *Repute Reference Manual* gives further information about the geotechnical theory that underpins Repute's calculations. The manual assumes you have a working knowledge of the geotechnical design of pile groups. This manual is provided in electronic (Adobe Acrobat) format only.

Repute's help system

Repute's help system contains detailed information about the program, including all the information contained in the *Repute User Manual*, plus additional information regarding Repute's user interface.

Help appears in a separate window to Repute, allowing you to view the help topics while you continue to work with Repute itself.

To open the help system:

- Press F1
- Click the Help button in any dialog box
- Choose a command from the **Help** menu

Technical support

Technical support for Repute is available direct from Geocentrix or through your local distributor. If you require technical support, please contact Geocentrix by any of these means:

Repute Technical Support Geocentrix Ltd Scenic House, 54 Wilmot Way Banstead, Surrey SM7 2PY, United Kingdom Please quote your licence number on all correspondence	Tel.: +44 (0)1737 373963 Fax: +44 (0)1737 373980 E-mail: support@geocentrix.co.uk Web: www.geocentrix.co.uk Please be at your computer and have your licence number ready when you call

Chapter 2
Installing and running Repute

Repute runs on most Microsoft Windows operating systems. Installation procedures vary slightly from one operating system to the next, as described in this chapter.

Although you can install Repute on as many computers as you like, you will only be able to run the program on those computers to which you attach an authorized security key.

System requirements

Repute runs on Microsoft Windows 95/98/Me and Microsoft Windows NT4/2000/XP and requires these minimum resources to function properly:

- Intel® Pentium® (or higher) processor
- 32 MB RAM
- At least 30Mb free space on your hard disk for a complete installation
- CD-ROM drive
- VGA or higher resolution monitor displaying 256 or more colours
- Any printer supported by Windows
- A mouse or other pointing device supported by Windows

To install Repute

Geocentrix CD Browser 2005
File View Install Manuals Tools
Geocentrix Software CD
Geocentrix® develops a range of geotechnical design programs, which follow the latest design standards and practices. The table below gives a brief description of each program. Click on the program's icon or name to visit the web page for that particular program. To install a program, click on the appropriate text/arrow at the end of each box.
ReWARD is one of the leading programs for the design of embedded retaining walls, incorporating several UK and international design standards, including BS 8002 and Eurocode 7.
Click here to install ReWARD.
Repute is an advanced computer program for determining the response of pile groups to 3-dimensional loading, using linear or non-linear soil models.
Click here to install Repute.
ReActiv is an interactive computer program for designing reinforced slopes in a wide variety of soil types using reinforced soil or soil nails.
Click here to install ReActiv.
Contact details
Geocentrix, Scenic House, 54 Wilmot Way, Banstead, Surrey, SM7 3PY, United Kingdom
www.geocentrix.co.uk
support@geocentrix.co.uk
+44(0)1737 373963 (tel)
+44(0)1737 372980 (fax)
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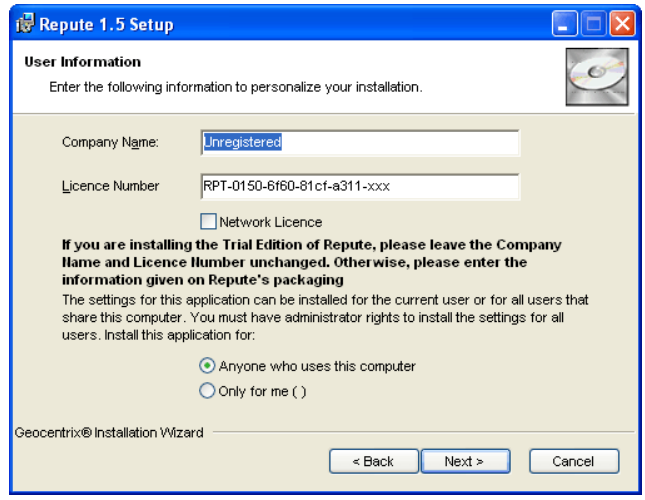
1. Remove any previous installation of Repute via Windows' Control Panel.
2. Insert the Geocentrix Software CD into your CD-ROM drive. The Geocentrix CD Browser should automatically appear on your screen. If not, click **Run...** on Windows' **Start** menu, type `X:\setup.exe` in the **Open** box (where X is the letter of your CD-ROM drive), and click **OK**.
3. Click on the text **"Click here to install Repute"** or the arrow to run the Repute installation program.
4. When asked "Do you want to run or save this file?" click **Run**. If a security

warning appears, click **Run**.

5. Follow the instructions on the welcome screen and then click **Next**.
6. Accept the license agreement and click **Next**.
7. Read the Readme Information for late-breaking news about Repute and click **Next**.
8. Enter your user information exactly as given on the program's packaging and click **Next**.
9. Select a destination folder and click **Next**.
10. Select an installation type and click **Next**.
11. Click **Next** to install the application.


Repute 1.5 Setup
User Information
Enter the following information to personalize your installation.
Company Name:
Unregistered
Licence Number
RPT-0150-6f60-81cf-a311-xxx
Network Licence
If you are installing the Trial Edition of Repute, please leave the Company Name and Licence Number unchanged. Otherwise, please enter the information given on Repute's packaging
The settings for this application can be installed for the current user or for all users that share this computer. You must have administrator rights to install the settings for all users. Install this application for:
Anyone who uses this computer
Only for me ( )
Geocentrix® Installation Wizard
< Back
Next >
Cancel

12. When the device driver installation (HDD_install) starts, please allow several minutes for it to complete. Then click **Close**.
13. When you are told that Repute has been successfully installed, click **Finish**.
14. Click **Exit** to close the Geocentrix CD Browser.

Screenshots are shown for Windows XP and may differ on other operating systems.

To run Repute

To run Repute, first connect the supplied key to your computer's USB/parallel port and then click **Start > All Programs > Geocentrix > Repute 1.5**.

*Note: in Windows XP and later, the **Programs** menu is called **All Programs**.*

To uninstall Repute

On Windows XP

1. Exit Repute
2. On Windows' **Start** menu, click **Control Panel**
3. Double-click on the **Add or Remove Programs** icon
4. Select **Change or Remove Programs** on the left hand side of the Add or Remove Programs window
5. Select Repute in the **Currently installed programs** box and click the **Remove** button that appears when you do so

6. Answer **Yes** when asked **Are you sure you want to remove Repute from your computer?**
7. When Windows has finished updating your system, click **Close** to close the Add or Remove Programs window
8. Close Windows' **Control Panel**

On Windows 95/98/Me/NT4/2000

1. Exit Repute
2. On Windows' **Start** menu, click **Settings > Control Panel**
3. Double-click on the **Add or Remove Programs** icon
4. On the **Install/Uninstall** page, select Repute from the list of programs installed on your system
5. Click the **Add/Remove** button
6. Select **Remove** in the Application Maintenance window and click **Next**
7. Click **Next** to confirm that you want to remove Repute
8. When Windows has finished updating your system, click **Finish**
9. Click **OK** to close the Add/Remove Programs window
10. Close Windows' **Control Panel**

Chapter 3
Overview

This chapter gives you an overview of Repute's main features.

Key features

The key features of Repute are:

- a notebook style user interface for easy entry of your pile, layer, and loading data
- a lightning-fast calculation engine based on the boundary-element method
- extensive reporting facilities via its in-built web browser, rich text viewer, and graph control
- a Pile Group Wizard to facilitate the speedy creation of large pile groups
- a detailed messaging system providing an audit trail of the program's operations
- built-in SI/Imperial unit converters
- extensive data-validation on data-entry and prior to calculation
- context-sensitive online help
- links to supporting material on the Geocentrix website

New to Repute 1.5

New calculation features:

- 6000 degree-of-freedom engine for very large pile groups

New user interface features:

- separate Data Input notebook, allowing easy entry of geotechnical, structural, and loading information
- new Results notebook, giving clear presentation of various formst of data outut (HTML reports, graphs, and text output)
- twin-display of input/ouput makes working with the program even easier
- re-sizable windows allows better use of available screen space

Extensive new graphing capabilities, including:

- change line colours, line weight, etc
- change graph title and font
- change axis titles and fonts

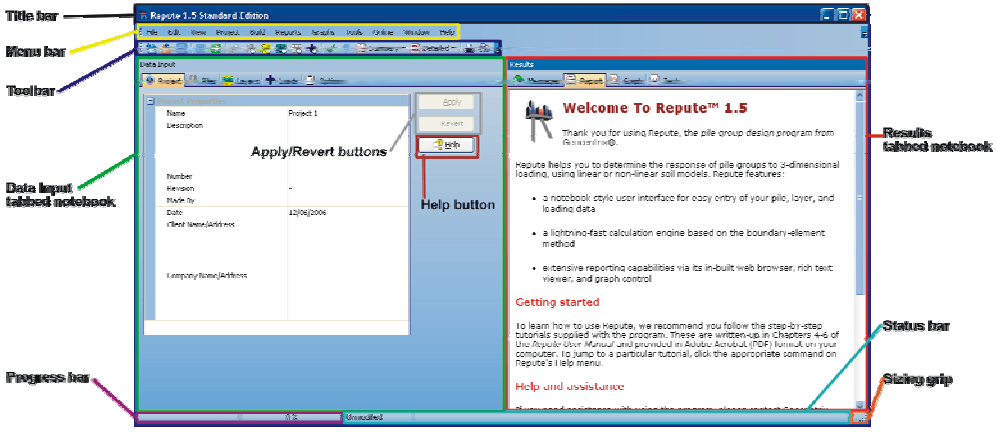
- show/hide selected lines
- fully cutomizable background grid
- new Graph menu provides quick access to results in visual form

Improved in Repute 1.5

- Re-designed data entry controls are now even easier to use
- Collapsable data entry controls allows information to be disclosed only when needed
- Re-designed main menu has more logical layout
- Smaller program footprint uses less of computer's hard disk
- Updated User Manual with revised Tutorials
- Simpler installation procedure
- Licence/dongle reminders made less frequent

User interface

Repute's user interface comprises a title bar, menu bar, toolbar, a tabbed notebook for the input data, a tabbed notebook for the project results, a status and progress bar, and sizing-grip.



Title bar

The title bar displays the program's name, version number, and edition. To view all of the program information, select **About Repute...** from the help menu. You may be asked to provide this information when contacting Geocentrix for technical support.

If you left-click on the Repute icon at the left-hand end of the title bar, a drop-down menu will appear with commands for sizing, moving, or closing Repute.

The row of buttons at the right-hand end of the title bar provide quick ways of minimizing, maximizing, or closing Repute.

Menu bar

Repute's menu bar provides groups of commands under the following headings:

- File
- Edit
- View
- Project
- Build
- Reports
- Graphs
- Tools
- Online
- Window
- Help

Further information about the commands that appear on these drop-down menus can be found in Repute's online help.

Commands that appear in grey are disabled (usually because that command is inappropriate or temporarily disallowed). For example, the **File > Save** command is disabled until you make changes to the current project.

Toolbar

The toolbar provides buttons that help you perform certain tasks quickly, without using the menus. The pictures on the toolbar buttons correspond to the pictures that appear to the left of the corresponding menu command.

If you move the cursor over a toolbar button, a popup window will appear giving a brief explanation of what the button does.

Those toolbar buttons that have a downwards pointing arrow next to them display a drop-

down menu when clicked.

Tabbed notebooks

Most of Repute's main window is taken up two tabbed notebooks, for Data Input and Results, which have separate pages for:

- Project, Piles, Layers, Loads, and Options under Data Input
- Messages, Reports, Graphs, and Text under Results

All pages under Data Input have a **Help** button in their top-right hand corners. When you click the **Help** button, Repute's help file opens and displays the topic which explains the items on the currently selected notebook page.

The Data Input pages also have **Apply** and **Revert** buttons in their top-right hand corners. When you make changes to the data displayed on any of these pages, you need to click **Apply** to commit those changes to Repute's internal memory. Alternatively, click **Revert** if you wish to discard the changes you have made.

If you forget to click **Apply** or **Revert** when leaving a data-entry page, Repute will remind you to do so.

Progress Bar

The progress bar gives an indication of how long a task takes to complete.

Status Bar

The status bar displays the name of the project you currently have opened and the word "Modified" if the project has been changed since it was last saved, or "Unmodified" if it has not been changed. In addition, the status bar shows the full file path of the project open (once it has been saved at least once).

Sizing grip

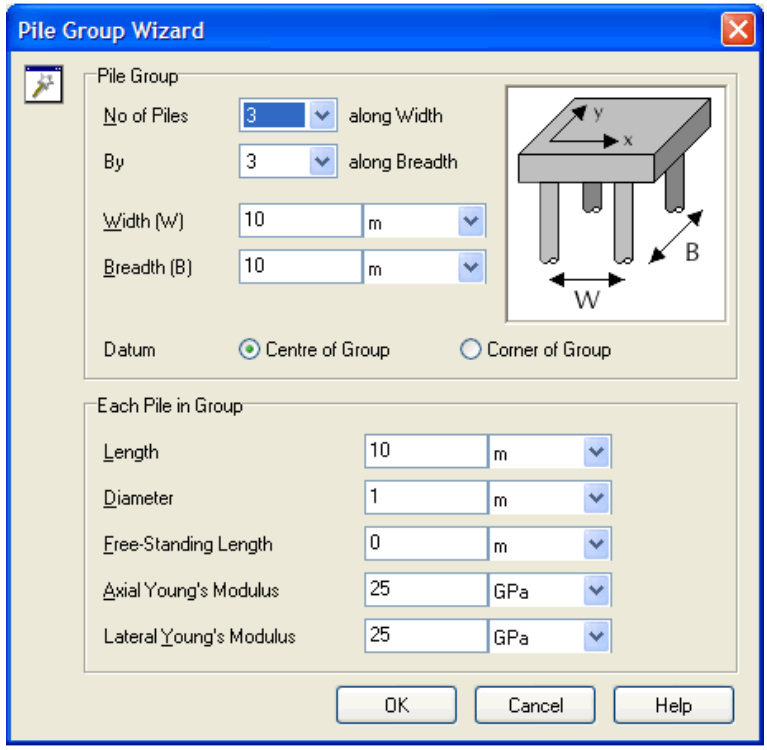
The sizing grip allows you to resize Repute's main window, which, for example, might be needed to see all the information given in one of Repute's detailed reports.

Tools

Repute provides a number of tools to increase your efficiency in using the program. You can see what tools are available to you by clicking on **Tools** on the menu bar.

Pile Group Wizard

The Pile Group Wizard is designed to speed up your use of Repute, by generating piles on a grid layout that you specify. The piles' properties can be edited via Repute's tabbed notebook once the Wizard has created them.



The best way to learn how to use the Pile Group Wizard is to follow Tutorials 1-3, which make extensive use of the wizard.

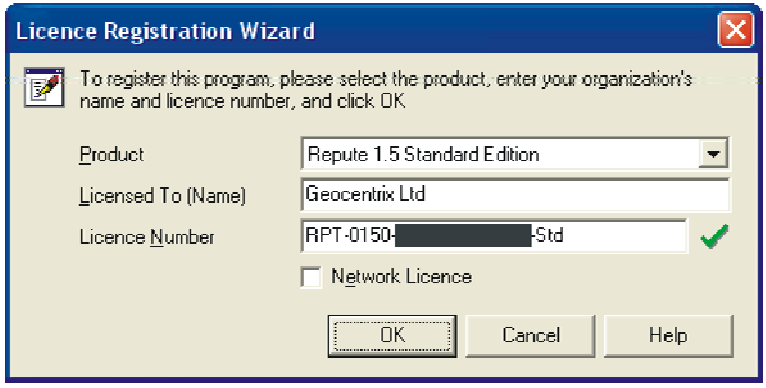
Licence Registration Wizard

The Licence Registration Wizard assists you in registering your copy of Repute, allowing you to unlock the particular edition you have purchased. Until Repute has been registered, only those features included in the Trial Edition of the program are available.

To register Repute:

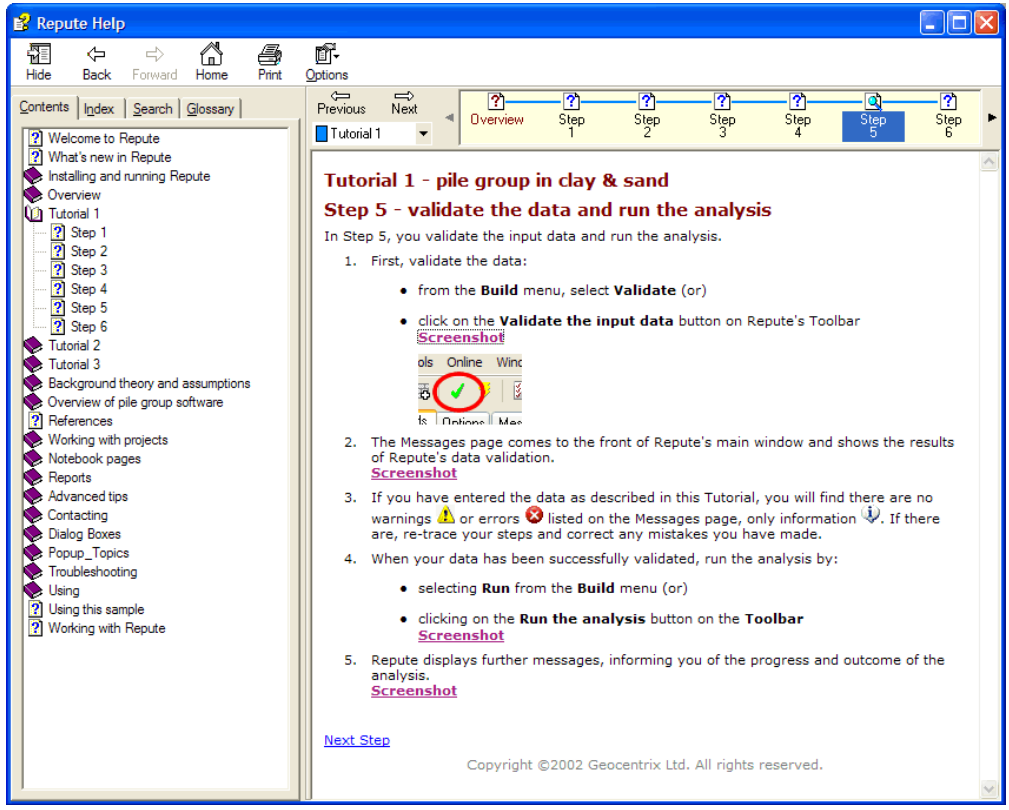
1. Select the **Product** you have purchased from those listed.
2. Enter your company's name in the **Licensed To (Name)** box.
3. Enter the licence number provided by Geocentrix in the **Licence Number** box.

4. If you have entered the information correctly, a green tick mark will appear beside the **Licence Number** box and the **OK** button will be enabled. If this does not occur, please contact Geocentrix for assistance.
5. Click **OK** to register the program.



Online help

Repute has a comprehensive online help system that includes all the information given in the *Repute User Manual*.


Repute Help
Hide
Back
Forward
Home
Print
Options
Contents
Index
Search
Glossary
Welcome to Repute
What's new in Repute
Installing and running Repute
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Troubleshooting
Using
Using this sample
Working with Repute
Previous
Next
Tutorial 1
Overview
Step 1
Step 2
Step 3
Step 4
Step 5
Step 6
Tutorial 1 - pile group in clay & sand
Step 5 - validate the data and run the analysis
In Step 5, you validate the input data and run the analysis.
1. First, validate the data:
from the Build menu, select Validate (or)
click on the Validate the input data button on Repute's Toolbar
Screenshot
2. The Messages page comes to the front of Repute's main window and shows the results of Repute's data validation.
Screenshot
3. If you have entered the data as described in this Tutorial, you will find there are no warnings or errors listed on the Messages page, only information. If there are, re-trace your steps and correct any mistakes you have made.
4. When your data has been successfully validated, run the analysis by:
selecting Run from the Build menu (or)
clicking on the Run the analysis button on the Toolbar
Screenshot
5. Repute displays further messages, informing you of the progress and outcome of the analysis.
Screenshot
Next Step
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To open Repute's online help

- Press F1
- Click the Help button in a dialog box
- Click the Help button on a notebook page
- Choose a command from the **Help** menu

To navigate Repute's online help

1. If the navigation panel is not showing, click on the **Show** button on the help window's toolbar
2. Click on the **Contents** tab to see the help file's table-of-contents, double-click a book to see more of the contents, and then click on the topic you want to display
3. Click on the **Index** tab and then double-click on a keyword to display a matching topic
4. Click on the **Search** tab, enter the keyword to find, click the **List Topics** button, and then select the topic you want to display

5. Click on the **Glossary** tab to display definitions of certain terms used in Repute

Chapter 4
Tutorial 1 – pile group in clay & sand

This tutorial demonstrates the basic features of Repute, by way of a worked example. Tutorial 1 shows you how to:

- Use the program's Pile Group Wizard
- Navigate Repute's notebook style interface
- View the results of your calculations

Worked example

The worked example involves the analysis of a group of 4 piles installed in stiff clay overlying dense sand.

- The ground conditions at the site comprise 8m of stiff clay (Young's modulus 40MPa vertically, 20MPa horizontally; Poisson's ratio 0.5) overlying dense sand (Young's modulus 50 + 10z MPa vertically and horizontally, where z is the depth below the top of the sand layer; Poisson's ratio 0.3). A linear-elastic soil model will be used.
- The piles will be installed on a 2 x 2 grid, at 3m spacing (centre-to-centre) along the edge of the grid. Each pile is 20m long, 1m in diameter, with a free-standing length of 0.5m and Young's modulus of 30GPa (both axially and laterally).
- You are interested in the displacements and rotation of the pile cap under a combined vertical load of 12MN, horizontal load of 1MN, and moment of 2MNm. The loads will be applied at the centre of the pile cap.

Steps

If Repute is not already running, double-click on the Repute icon to load the program into your computer's memory. Once the "splash screen" has disappeared, Repute displays its main user interface.

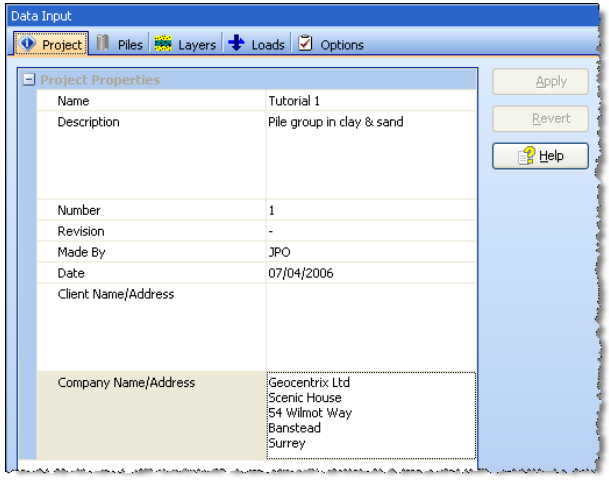
- In Step 1, you enter basic project information, such as your client's name and the project description.
- In Step 2, you define the size of the pile group and let Repute create the piles for you.
- In Step 3, you enter the properties of the soil layers.
- In Step 4, you specify the loads applied to the pile group.
- In Step 5, you validate the input data and run the analysis.

- In Step 6, you review the results of the analysis.

Step 1 - enter basic project information

In Step 1, you enter basic project information, such as your client's name and the project description.

1. If the Project page is not already showing, click on the **Project** tab in Repute's main window, or from the **View** menu, select Project. The Project page comes to the front of Repute's main window.
2. In the **Name** box, change “Project 1" to "Tutorial 1". When you do so, the **Apply** and **Revert** buttons are enabled, reminding you that you have made changes to the data on this page.
3. Enter “Pile group in clay & sand” in the **Description** box.
4. Enter the number 1 in the **Number** box.
5. Enter your name or initials in the **Made By** box.
6. Enter your company's name and address in the **Company Name** box.



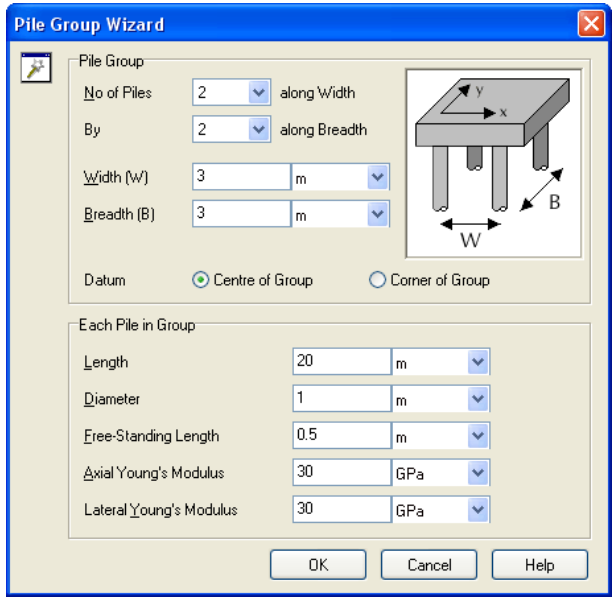
7. Click the **Apply** button to commit this information to Repute’s internal memory. When you do so, the **Apply** and **Revert** buttons are disabled, indicating that your changes have been committed to memory.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 1`, under the name `Step1.rpx`.

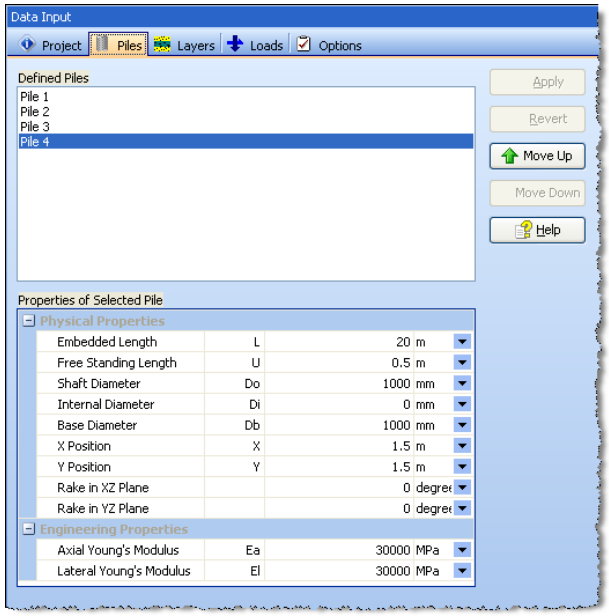
Step 2 - define the pile group

In Step 2, you define the size of the pile group and let Repute create the piles for you.

1. From the **Tools** menu, select **Pile Group Wizard**. The Pile Group Wizard appears.
2. Enter the number of piles in the group (in this case 2 x 2). You can add or delete piles at a later time via Repute's Piles window.
3. Enter the dimensions of the pile group, measured from the centre of the first pile to the centre of the last pile along each side of the group (in this case, 3m x 3m).
4. Select the position of the datum (this determines where x and y dimensions are measured from). Choose **Centre of Group** for this example.
5. Enter the length (20m), diameter (1m), and free-standing length (0.5m) of the piles. You can alter the dimensions of any pile at a later time via Repute's Piles window.
6. Enter the axial and lateral Young's moduli (30 GPa) of the piles. Again, you can alter these values later via Repute's Piles window.



7. Click **OK** to create the pile group. The Piles page comes to the front of Repute's main window.



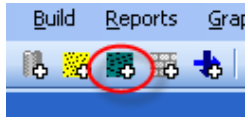
8. You can review the properties of each pile by clicking on their names in the **Defined Piles** box.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 1`, under the name `Step2.rpx`.

Step 3 - enter the layers

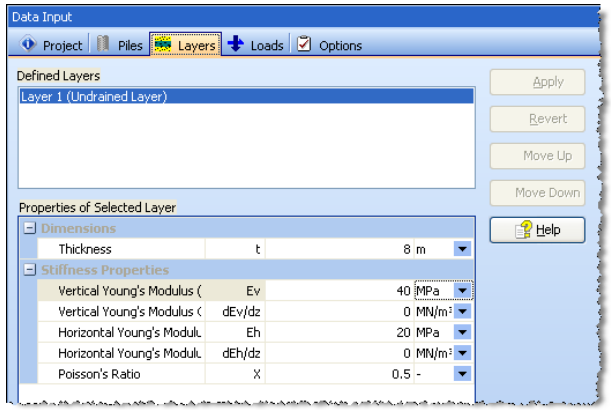
In Step 3, you enter the properties of the soil layers.

1. Click on the **Layers** tab in Repute's main window or from the **View** menu, select **Layers**. The Layers page comes to the front of Repute's main window.
2. First, create the clay layer:
   - from the **Project** menu, select **Add Undrained Layer** (or)
   - click on the **Create a new undrained layer** button on Repute's Toolbar.

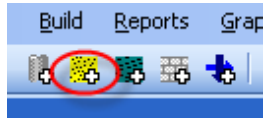


3. A new layer is created and added to the **Defined Layers** box.
4. Enter the clay's **Thickness** (8m), **Vertical Young's Modulus (At Top)** (40MPa), and **Horizontal Young's Modulus (At Top)** (20MPa). For undrained layers, **Poisson's**

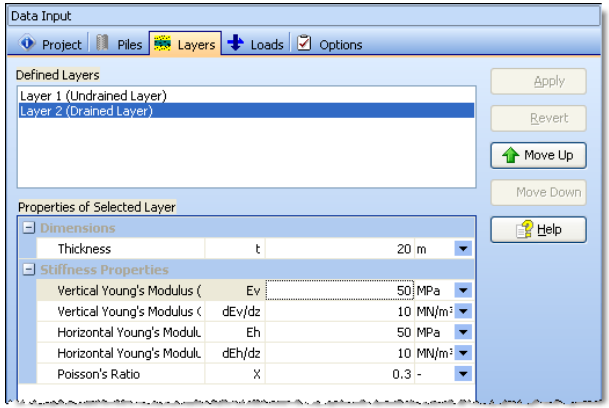
Ratio is automatically set to 0.5.



5. If you need to change the units of any property, you can do so by clicking on the corresponding down-arrow and selecting from the list of units given. The value entered in the attached edit box will change accordingly.
6. Click **Apply** to save the entered values for this layer.
7. Next, create the sand layer:
   - from the **Project** menu, select **Add Drained Layer** (or)
   - click on the **Create a new drained layer** button on Repute's Toolbar



8. A second layer is created and added to the **Defined Layers** box.
9. Leave the layer's **Thickness** at its default value (20m) and enter its **Vertical Young's Modulus (At Top)** (50MPa) and **Gradient** (10MN/m^3), and **Horizontal Young's Modulus (At Top)** and **Gradient** (both same as vertical). For drained layers, **Poisson's Ratio** is automatically set to 0.3.



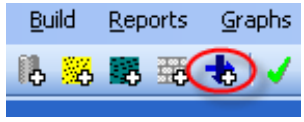
10. Click **Apply** to save the entered values for Layer 2.
11. Click on Layer 1 and Layer 2 in the **Defined Layers** box to review the properties you have entered for each layer.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 1`, under the name `Step3.rpx`.

Step 4 - specify the loads

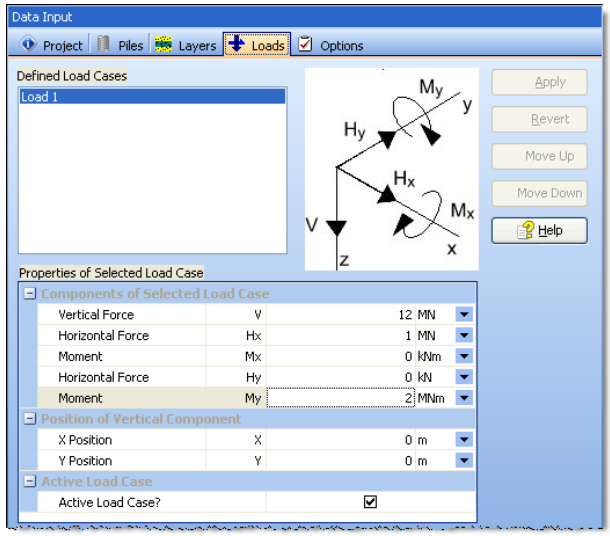
In Step 4, you specify the loads applied to the pile group.

1. Click on the **Loads** tab in Repute's main window or from the **View** menu, select **Loads**. The Loads page comes to the front of Repute's main window.
2. To create a new load case:
   - from the **Project** menu, select **Add Load** (or)
   - click on the **Create a new load** button on Repute's Toolbar



3. A new load case is created and added to the **Defined Load Cases** box.
4. Enter the **Vertical Force** V (12MN), **Horizontal Force Hx** (1MN), and **Moment My** (2MNm) in the appropriate boxes. It is usually easier to change the units (to MN or MNm in these cases) before entering the values.
5. Because, in Step 2, we set the pile cap's datum to Centre of Group, here we set the **X** position of the vertical load to 0m (i.e. at the centre of the pile group).
6. Since this is the only load case defined at present, Repute automatically makes it

the active load case.



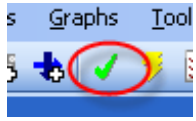
7. Click **Apply** to save the entered values for this load case.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 1`, under the name `Step4.rpx`.

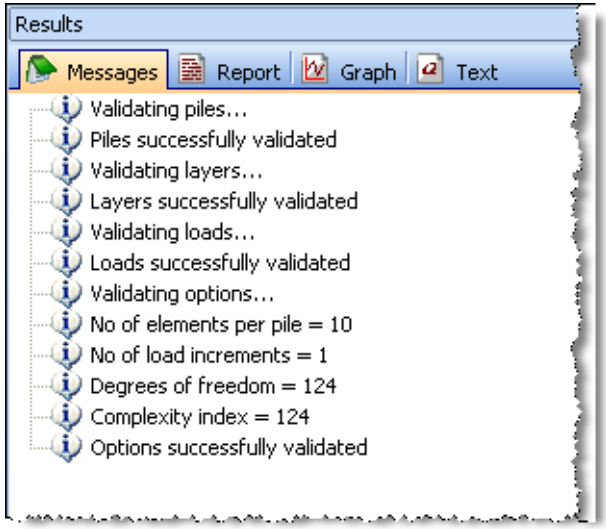
Step 5 - validate the data and run the analysis

In Step 5, you validate the input data and run the analysis.

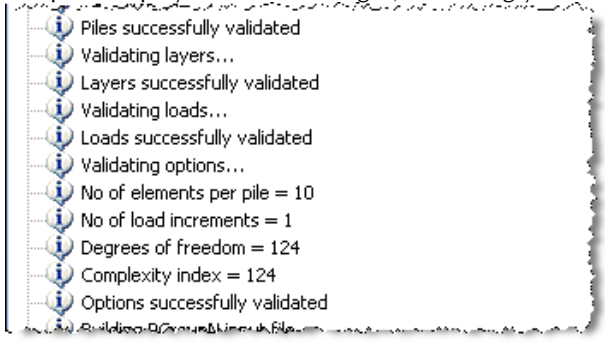
1. First, validate the data:
   - from the **Build** menu, select **Validate** (or)
   - click on the **Validate the input data** button on Repute's Toolbar



2. The Messages page comes to the front of Repute's main window and shows the results of Repute's data validation.



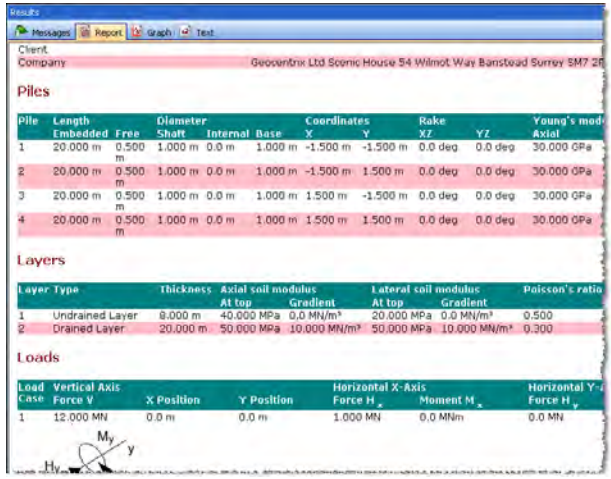
3. If you have entered the data as described in this Tutorial, you will find there are no warnings or errors listed on the Messages page, only information. If there are, re-trace your steps and correct any mistakes you have made.
4. When your data has been successfully validated, save your work by selecting **Save Project As** from the **File** menu, choose where to save the project and what to call it, and click the **Save** button. Repute automatically adds ".rpx" to the filename you specify.
5. Then run the analysis by:
   - selecting **Run** from the **Build** menu (or)
   - clicking on the **Run the analysis** button on the Toolbar
6. Repute displays further messages, informing you of the outcome of the analysis.



Step 6 - review the results of the analysis

In Step 6, you review the results of the analysis.

1. From the **Reports** menu, select **Summary**.
2. From the **Summary** menu, select **All Input**. The Reports page comes to the front of Repute's main window and shows a report giving a summary of all your input parameters. (You may need to enlarge/maximize Repute's main window to see all of this report.)


Results

Messages | Report | Graph | Text

Client

Company Geocentrix Ltd Scenic House 54 Wilmot Way Banstead Surrey SM7 2

Piles

Pile	Length		Diameter			Coordinates		Rake		Young's mod
	Embedded	Free	Shaft	Internal	Base	X	Y	XZ	YZ	Axial
1	20.000 m	0.500 m	1.000 m	0.0 m	1.000 m	-1.500 m	-1.500 m	0.0 deg	0.0 deg	30.000 GPa
2	20.000 m	0.500 m	1.000 m	0.0 m	1.000 m	-1.500 m	1.500 m	0.0 deg	0.0 deg	30.000 GPa
3	20.000 m	0.500 m	1.000 m	0.0 m	1.000 m	1.500 m	-1.500 m	0.0 deg	0.0 deg	30.000 GPa
4	20.000 m	0.500 m	1.000 m	0.0 m	1.000 m	1.500 m	1.500 m	0.0 deg	0.0 deg	30.000 GPa

Layers

Layer	Type	Thickness	Axial soil modulus		Lateral soil modulus		Poisson's ratio
			At top	Gradient	At top	Gradient	
1	Undrained Layer	8.000 m	40.000 MPa	0.0 MN/m³	20.000 MPa	0.0 MN/m³	0.500
2	Drained Layer	20.000 m	50.000 MPa	10.000 MN/m³	50.000 MPa	10.000 MN/m³	0.300

Loads

Load Case	Vertical Axis Force V	X Position	Y Position	Horizontal X-Axis Force H x	Moment M x	Horizontal Y-A Force H y
1	12.000 MN	0.0 m	0.0 m	1.000 MN	0.0 MNm	0.0 MN

My y Hy

3. Next, select **Key Results** from the **Reports > Summary** menu to see a report summarizing the deflections and rotation of the pile cap.
4. Experiment with the other reports listed on Repute's **Reports > Summary** menu.
5. To print a report:
   - right-click anywhere on a report to display the browser's context-sensitive popup menu and select **Print** from the popup menu
   - select **Print...** from Repute's **File** menu
6. If you wish to save your work again then click the **Save** button.
7. If you do not wish to proceed with Tutorial 2 at this time, you can exit Repute by selecting **Exit** from the **File** menu.

You will find a copy of this project in its final state in the folder `Projects\Tutorial 1`, under the name `Step6.rpx`.

What next?

Tutorial 2 presents a non-linear analysis of a pile group in stiff clay overlying rock.

Tutorial 3 looks at the more complicated case of an asymmetric pile group under 3-dimensional loading.

Chapter 5
Tutorial 2 – non-linear analysis of pile group in stiff clay overlying rock

This tutorial presents a non-linear analysis of a pile group installed in stiff clay overlying rock. Tutorial 2 also shows you how to:

- Specify a non-linear analysis
- Introduce a rigid layer into the calculations
- Produce a load-displacement graph for the pile cap
- Print the results of your calculations

Worked example

The worked example involves the analysis of a group of 4 piles installed in stiff clay overlying rock.

- The ground conditions at the site comprise 35m of stiff clay (Young's modulus 75 + 10z MPa vertically and half that horizontally, where z is the depth below the top of the layer; Poisson's ratio 0.5) overlying a rigid layer of rock.
- A non-linear soil model will be used for the clay, which has a unit weight of 19.8kN/m^3, undrained strength of 75 + 10z kPa, and adhesion factor of 0.5.
- The water table is at the ground surface.
- The piles will be installed on a 2 x 2 grid, at 3m spacing (centre-to-centre) along the edge of the grid. Each pile is 20m long, 1m in diameter, with a free-standing length of 0.5m and Young's modulus of 30GPa (both axially and laterally). This is the same pile group as was used in Step 2 of Tutorial 1.
- You are interested in the displacements and rotation of the pile cap under a combined vertical load of 20MN, horizontal load of 2MN, and moment of 3MNm. The loads will be applied at the centre of the pile cap.
- Hyperbolic curve-fitting constants of 0.5 (for the shaft), 0.99 (for the base), and 0.9 (for lateral response) should be used.
- Two analyses will be run, one without any limit on the mobilized shaft stresses and one with a limit of 100kPa.

Steps

If Repute is not already running, double-click on the Repute icon to load the program into

your computer's memory. Once the "splash screen" has disappeared, Repute displays its main user interface.

If you are following this tutorial having just completed Tutorial 1, click **New Project** on the **File** menu to create a new (blank) project. You will be prompted to save your work if you have not already done so.

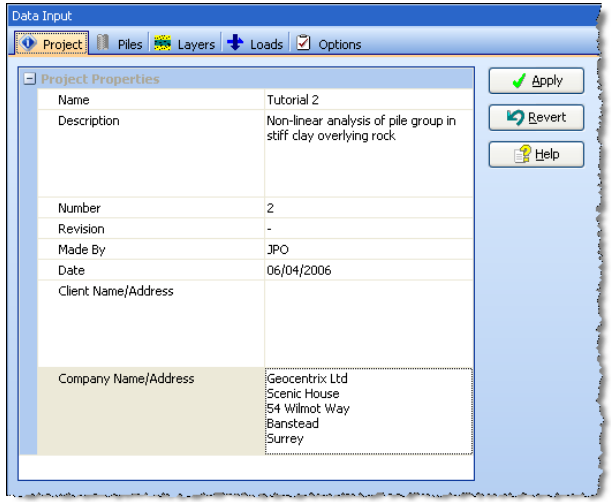
In this tutorial:

- In Step 1, you enter basic project information, such as your client's name and the project description.
- In Step 2, you change the analysis to non-linear and enter parameters needed to support this calculation.
- In Step 3, you enter the properties of the soil and rock layers.
- In Step 4, you define the pile group and let Repute create the piles for you..
- In Step 5, you specify the loads.
- In Step 6, you run the analysis.
- In Step 7, you display the load-displacement curve for the pile group.
- In Step 8, you apply limiting stresses along the pile shaft and re-run the analysis to see the effect.

Step 1 - enter basic project information

In Step 1, you enter basic project information, such as your client's name and the project description.

1. If the Project page is not already showing, click on the Project tab in Repute's main window or from the Window menu, select Project. The Project page comes to the front of Repute's main window.
2. Enter "Tutorial 2" in the **Name** box. When you do so, the **Apply** and **Revert** buttons are enabled, reminding you that you have made changes to the data on this page.
3. In the **Description** box, enter "Non-linear analysis of pile group in stiff clay overlying rock".
4. Enter the number 2 in the **Number** box.
5. Enter your name or initials in the **Made By** box.
6. Enter your company's name and address in the **Company Name** box.



7. Click the **Apply** button to commit this information to Repute's internal memory. When you do so, the **Apply** and **Revert** buttons are disabled, indicating that your changes have been committed to memory.

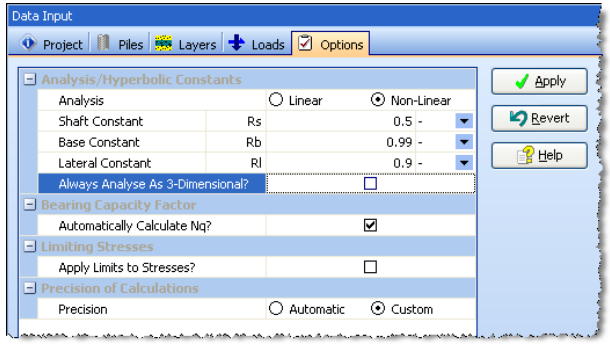
You will find a copy of this project in its current state in the folder `Projects\Tutorial 2`, under the name `Step1.rpx`.

Step 2 - change the analysis to non-linear

In Step 2, you change the analysis to non-linear and enter parameters needed to support this calculation.

By default, Repute determines the pile group's response to load using a linear boundary element analysis. This is the simplest (but least realistic) of the analyses that Repute can perform. To specify a non-linear analysis:

1. Click on the **Options** tab in Repute's main window or from the **View** menu, select Options. The Options page comes to the front of Repute's main window.
2. If not already set, change the **Analysis** to **Non-linear**. The **Shaft**, **Base**, and **Lateral** boxes will appear, since these are needed for a non-linear analysis, and other options will be enabled.
3. Enter values of 0.5, 0.99, and 0.9 for the shaft, base, and lateral **Hyperbolic Constants**, respectively.
4. Clear the checkbox labelled **Always Analyse As 3-Dimensional**. This will allow Repute to simplify - and speed up - the analysis, provided the pile group and loading are both symmetrical about the X-axis.



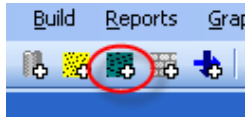
5. Click the **Apply** button to commit this information to Repute's internal memory.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 2`, under the name `Step2.rpx`.

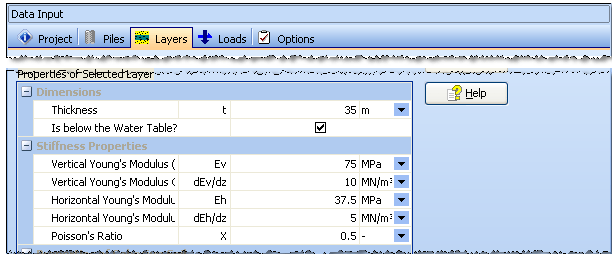
Step 3 - enter the soil and rock layers

In Step 3, you enter the properties of the soil and rock layers.

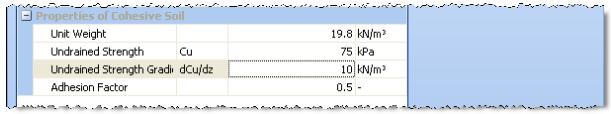
1. Click on the **Layers** tab in Repute's main window or from the **View** menu, select **Layers**. The Layers page comes to the front of Repute's main window.
2. First, create the clay layer:
   - from the **Project** menu, select **Add Undrained Layer** (or)
   - click on the **Create a new undrained layer** button on Repute's Toolbar.



3. A new layer is created and added to the **Defined Layers** box.
4. Enter the clay's **Thickness** (35m), **Vertical Young's Modulus (At Top)** (75MPa) and **Gradient** (10MN/m^3), and **Horizontal Young's Modulus (At Top)** (37.5MPa) and **Gradient** (5MN/m^3). For undrained layers, **Poisson's Ratio** is automatically set to 0.5.

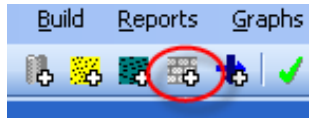


5. Next, enter the soil's **Unit Weight** (19.8kN/m^3), **Undrained Strength** (75kPa) and **Gradient** (10kN/m^3), and **Adhesion Factor** (0.5).


Properties of Cohesive Soil
Unit Weight 19.8 kN/m³
Undrained Strength Cu 75 kPa
Undrained Strength Gradi dCu/dz 10 kN/m³
Adhesion Factor 0.5 -

6. Make sure the **Layer is below the Water Table** box is ticked.

7. Click **Apply** to save the entered values for Layer 1.
8. Next, create the rock layer:
   - from the **Project** menu, select **Add Rigid Layer** (or)
   - click on the **Create a new rigid layer** button on Repute's Toolbar



9. A second layer is created and added to the **Defined Layers** box.
10. Because rigid layers have no properties that you need to set, the **Dimensions of Selected Layer**, **Properties of Selected Layer**, and **Properties of ... Soil boxes** are hidden.

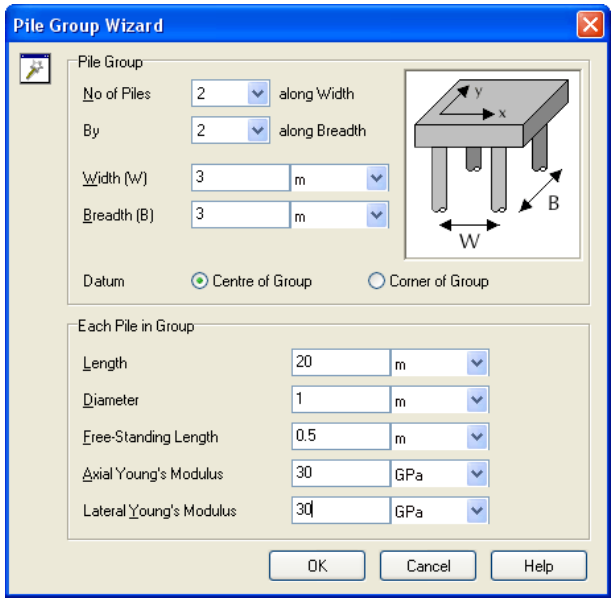
You will find a copy of this project in its current state in the folder `Projects\Tutorial 2`, under the name `Step3.rpx`.

Step 4 - define the pile group

In Step 4, you define the size of the pile group and let Repute create the piles for you.

1. From the **Tools** menu, select **Pile Group Wizard**. The Pile Group Wizard appears.
2. Enter the number of piles in the group (2 x 2) and its dimensions (3m x 3m).
3. Select the position of the datum (**Centre of Group**).

4. Enter the length (20m), external diameter (1m), free-standing length (0.5m), and axial and lateral Young's moduli (30 GPa) of the piles.



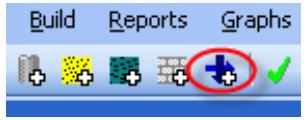
5. Click **OK** to create the pile group.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 2`, under the name `Step4.rpx`.

Step 5 - specify the loads

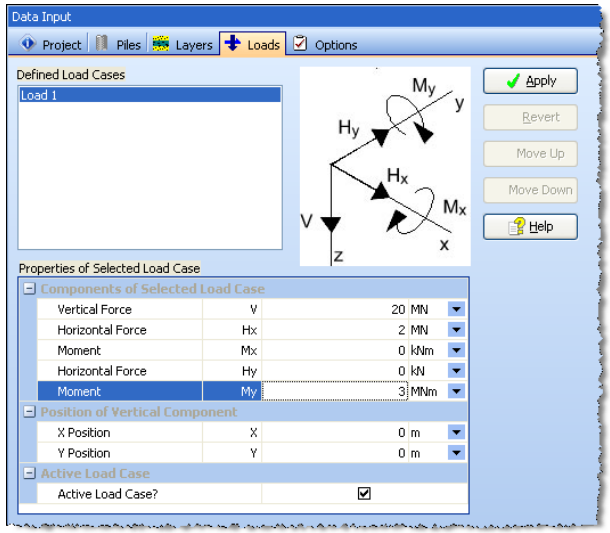
In Step 5, you specify the loads applied to the pile group.

1. Click on the **Loads** tab in Repute's main window or from the **View** menu, select **Loads**. The Loads page comes to the front of Repute's main window.
2. To create a new load case:
   - from the **Project** menu, select **Add Load** (or)
   - click on the **Create a new load** button on Repute's Toolbar



3. A new load case is created and added to the **Defined Load Cases** box.

4. Enter the **Vertical Force** V (20MN), **Horizontal Force Hx** (2MN), and **Moment My** (3MNm) in the appropriate boxes. Set the **X** position of the vertical load to 0m (i.e. at the centre of the pile group).



5. Click **Apply** to save the entered values for this load case.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 2`, under the name `Step5.rpx`.

Step 6 - run the analysis

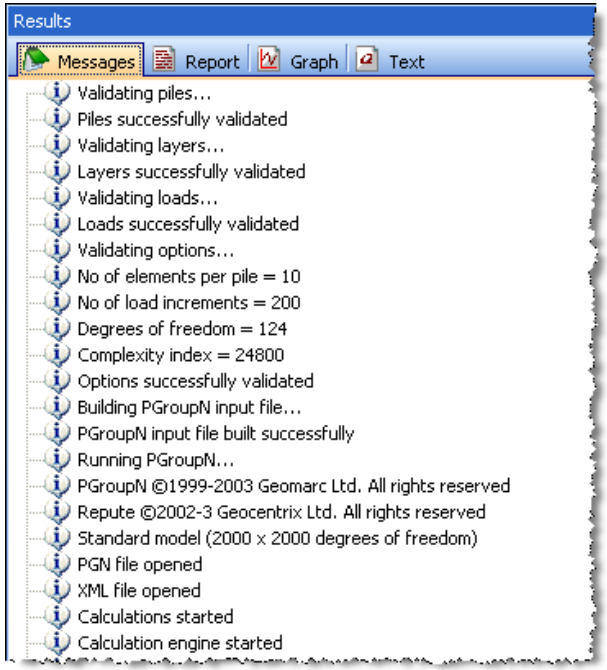
In Step 6, you run the analysis.

1. Before running the analysis, save your work by selecting **Save Project As** from the **File** menu, choose where to save the project and what to call it, and click the **Save** button. Repute automatically adds ".rpx" to the filename you specify.

2. To run the analysis:

   - select **Run** from the **Build** menu (or)
   - click on the **Run the analysis** button on the Toolbar

3. Repute automatically validates your input data and then performs the analysis. When it has finished these tasks, the Messages page comes to the front of Repute's main window.

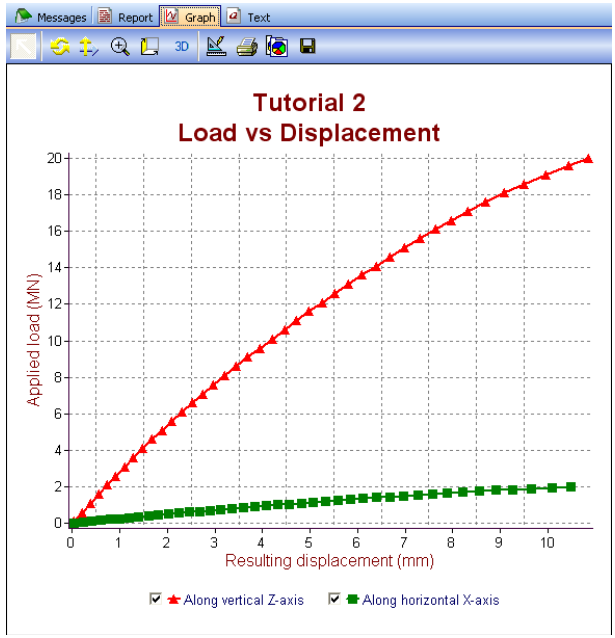


4. If you have entered the data as described in this Tutorial, you will find there are no warnings or errors listed on the Messages page, only information. If there are, re-trace your steps and correct any mistakes you have made.

Step 7 - display the load-displacement curve for the pile group

In Step 7, you display the load-displacement curve for the pile group.

1. From the **Graphs** menu, select **Load vs Displacement**. The Graphs page comes to the front of Repute's main window and shows a graph of vertical and horizontal load against their corresponding displacements, for the pile group.

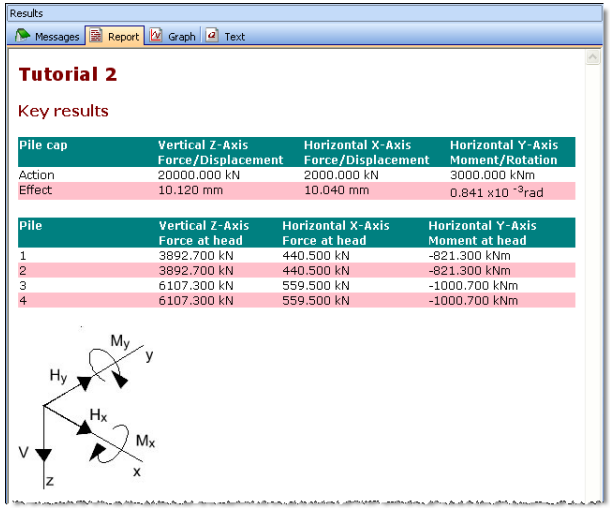


2. Next, select **Moment vs Rotation** from the **Graphs** menu to see a graph of applied moment against the resulting rotation.
3. Experiment with the other reports listed on Repute's **Graphs** menu. Note that the graphs of pile forces, bending moments, and stresses are produced for whichever pile is currently selected on the **Piles** page.
4. To print a graph:
   - right-click anywhere on a report to display the graph's context-sensitive popup menu and select **Print** from the popup menu
   - select **Print...** from Repute's **File** menu

Step 8 - apply limiting stresses

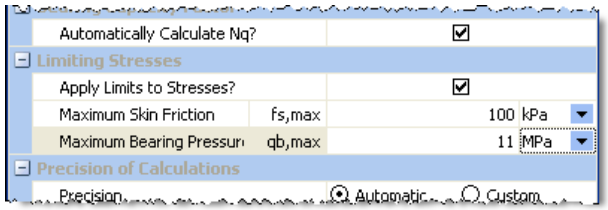
In Step 8, you apply limiting stresses along the pile shaft and re-run the analysis to see the effect.

1. First, make a note of the vertical displacement of the pile group without any limiting stresses applied:
   - From the **Reports** menu, select **Summary**.
   - From the **Summary** menu, select **Key Results**. The Reports page comes to the front of Repute's main window and shows a report giving the key results from the analysis. Note the value of the vertical displacement (10.12mm).



2. Next, click on the **Options** tab in Repute's main window or from the **View** menu, select **Options**. The Options page comes to the front of Repute's main window.

3. Tick the **Apply Limits to Stresses** box. The **Maximum Skin Friction** and **Maximum Bearing Pressure** boxes will appear. Enter values of 100kPa and 11MPa respectively in these boxes.



4. Click the **Apply** button to commit this information to Repute's internal memory.

5. Re-run the analysis:

   - select **Run** from the **Build** menu (or)
   - click on the **Run the analysis** button on the Toolbar

6. Repute re-validates your input data and then performs the modified analysis.

7. Now inspect the vertical displacement of the pile group with limiting stresses applied:

   - From the **Reports** menu, select **Summary**.
   - From the **Summary** menu, select **Key Results**. The Reports page comes to the front of Repute's main window and shows a report giving the key results from the analysis. The value of the vertical displacement has changed to 10.86mm, i.e. there is 0.74mm more vertical movement when limiting stresses are

applied.

8. You may want to review the effect of this change on the pile group's load-displacement curves, by displaying the graphs available from Repute's **Graphs** menu.
9. If you wish to save your work again then click the save button
10. If you do not wish to proceed with Tutorial 3 at this time, you can exit Repute by selecting **Exit** from the **File** menu.

You will find a copy of this project in its final state in the folder `Projects\Tutorial 2`, under the name `Step8.rpx`.

What next?

Tutorial 3 looks at the more complicated case of an asymmetric pile group under 3-dimensional loading.

Chapter 6
Tutorial 3 – asymmetric pile group under 3D loading

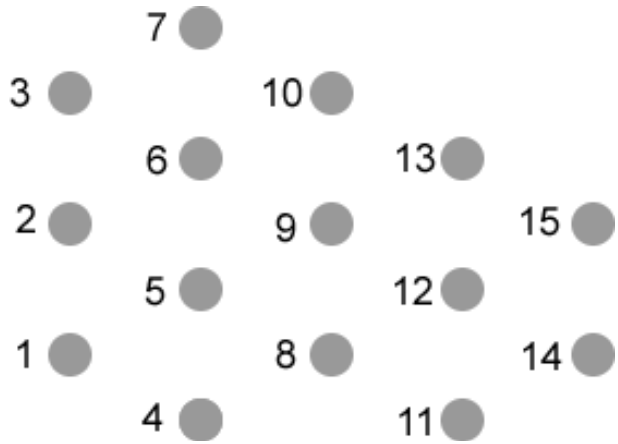
This tutorial considers a more complicated project than Tutorials 1 and 2: that of an asymmetric pile group under general 3-dimensional loading. Tutorial 3 shows you how to:

- Modify an existing project
- Change the location of individual piles within a pile group
- Obtain a plan diagram showing the layout of the piles
- Specify 3D loading

Worked example

The worked example involves the analysis of a group of 15 piles installed in stiff clay overlying dense sand.

- The ground conditions at the site are identical to those in Tutorial 1.
- The piles will be installed on an irregular grid, as shown below. The spacing between adjacent rows is 3m in the X direction and 1.5m in the Y direction.



- Each pile is 20m long, 1m in diameter, and has a Young's modulus of 30GPa (both axially and laterally).
- You are interested in the displacements and rotation of the pile cap under a combined vertical load of 50MN, horizontal loads of 10MN (in the X-direction) and 7MN (in the Y-direction), and moments of 5MNm (in the XZ-plane) and 3MNm (in

the YZ-plane). The vertical load will be applied on the pile cap at the location of Pile 9.

Steps

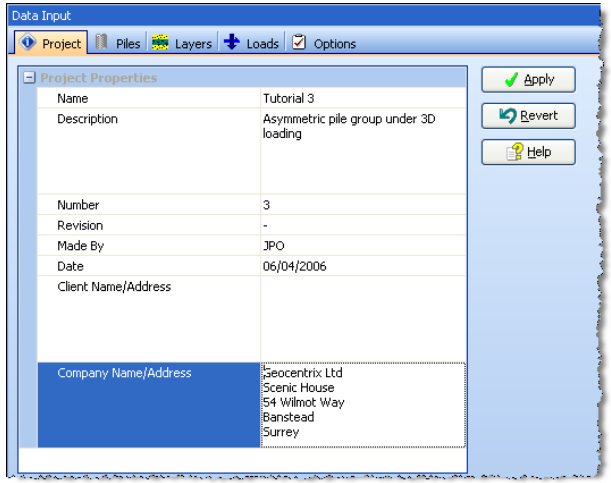
If Repute is not already running, double-click on the Repute icon to load the program into your computer's memory. Once the "splash screen" has disappeared, Repute displays its Project window.

- In Step 1, you open an existing project and modify its project information.
- In Step 2, you specify the 3-dimensional loading on the pile group.
- In Step 3, you create a new pile group.
- In Step 4, you move the piles to obtain an asymmetric layout.
- In Step 5, you review the pile layout to check for any mistakes.
- In Step 6, you run the analysis and view the results.

Step 1 - open and modify an existing project

In Step 1, you open an existing project and modify its project information.

1. From the **File** menu select **Open Project...**, navigate to the folder `Projects\Tutorial 3` and open the file `Tutorial1.rpx` (this is a copy of the file that was saved at the end of Tutorial 1). If you already have another project open, you will be prompted to save your work if you have not already done so.
2. Click on the **Project** tab in Repute's main window or from the **View** menu, select **Project**. The Project page comes to the front of Repute's main window.
3. Change the **Name** to "Tutorial 3", the **Description** to "Asymmetric pile group under 3D loading", and the **Number** to 3.



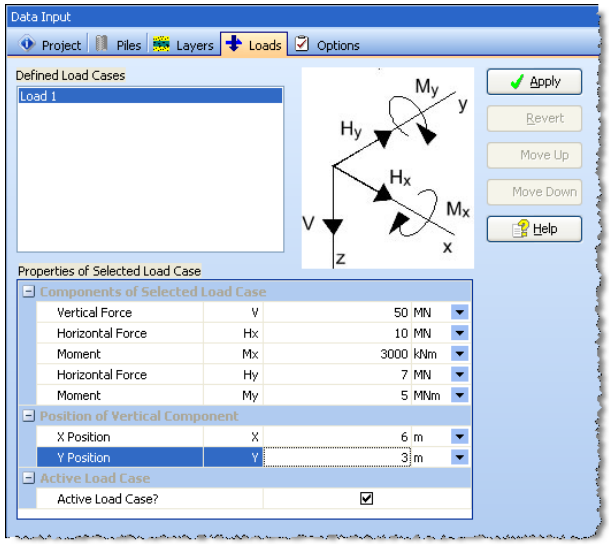
4. Click the **Apply** button to commit this information to Repute's internal memory.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 3`, under the name `Step1.rpx`.

Step 2 - specify the 3-dimensional loading

In Step 2, you specify the 3-dimensional loading on the pile group.

1. Click on the **Loads** tab in Repute's main window or from the **View** menu, select **Loads**. The Loads page comes to the front of Repute's main window.
2. Enter the **Vertical Force V** (50MN), **Horizontal Force Hx** (10MN), **Moment Mx** (3MNm), **Horizontal Force Hy** (7MN), and **Moment My** (5MNm) in the appropriate boxes. It is usually easier to change the units (to MN or MNm in these cases) before entering the values.
3. In this worked example, we will set the pile cap's datum at the location of Pile 1 (near the corner of the pile group) and apply the vertical force at the location of Pile 9 (i.e. at an **X** position of 6m and **Y** position of 3m). Enter these values in the appropriate boxes.



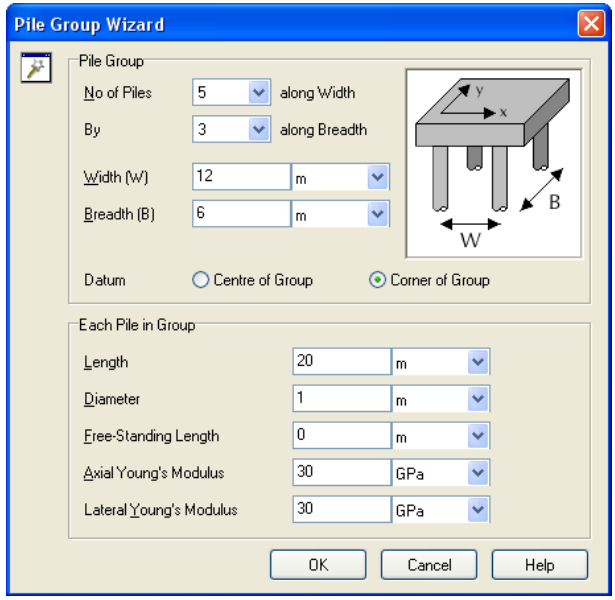
4. Click **Apply** to save the values entered for this load case.

You will find a copy of this project in its current state in the folder `Projects\Tutorial 3`, under the name `Step2.rpx`.

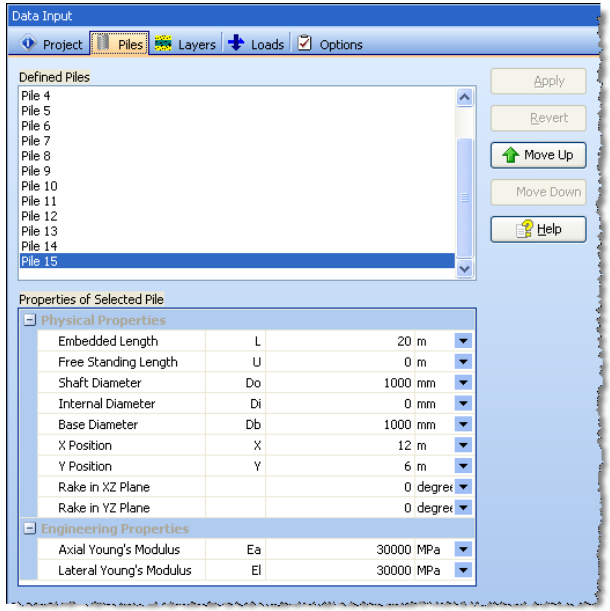
Step 3 - create a new pile group

In Step 3, you create a new pile group.

1. Click on the **Piles** tab in Repute's main window or from the **View** menu, select **Piles**. The Piles page comes to the front of Repute's main window.
2. From the **Tools** menu, select **Pile Group Wizard**. A box appears with the message "`Running the Pile Group Wizard will clear all the existing piles. Do you want to continue?`" Answer **Yes**. The Pile Group Wizard appears.
3. Enter the number of piles in the group (in this case 5 x 3).
4. Enter the dimensions of the pile group, measured from the centre of the first pile to the centre of the last pile along each side of the group (12m x 6m).
5. Select the position of the datum (this determines where X and Y dimensions are measured from). Choose **Corner of Group** for this example.
6. Enter the length (20m) and external diameter (1m) of the piles. You can alter the dimensions of any pile at a later time via Repute's Piles window.
7. Enter the axial and lateral Young's moduli (30 GPa) of the piles. Again, you can alter these values later via Repute's Piles window.



8. Click **OK** to create the pile group.



You will find a copy of this project in its current state in the folder `Projects\Tutorial 3`, under the name `Step3.rpx`.

Step 4 - move the piles into an asymmetric layout

In Step 4, you move the piles to obtain an asymmetric layout.

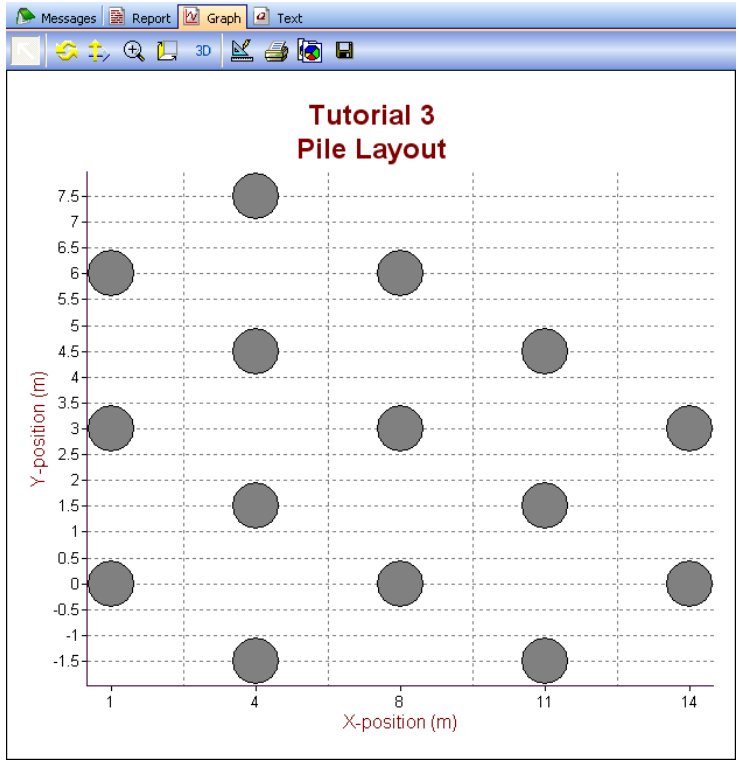
1. Selecting each pile in the **Defined Piles** box in turn, edit their **X** and **Y Positions** as follows:
   - Piles 1, 2, and 3: leave unchanged
   - Pile 4: change the **Y Position** to -1.5m and click **Apply**
   - Pile 5: change the **Y Position** to +1.5m and click **Apply**
   - Pile 6: change the **Y Position** to +4.5m and click **Apply**
   - Piles 7, 8, and 9: leave unchanged
   - Pile 10: change the **Y Position** to -1.5m and click **Apply**
   - Pile 11: change the **Y Position** to +1.5m and click **Apply**
   - Pile 12: change the **Y Position** to +4.5m and click **Apply**
   - Piles 13 and 14: leave unchanged
   - Pile 15: change the **X Position** to +3m and the **Y Position** to +7.5m and click **Apply**
2. From the **Edit** menu, select **Sort** to re-order the piles according to their X and Y positions (Pile 15 will become Pile 7 and Piles 7-14 will become Piles 8-15).

You will find a copy of this project in its current state in the folder `Projects\Tutorial 3`, under the name `Step4.rpx`.

Step 5 - review the pile layout

In Step 5, you review the pile layout to check for any mistakes.

1. From the **Graphs** menu, select **Pile Layout**. The Reports page comes to the front of Repute's main window and shows a plan view of the piles, with the X and Y axes centred on Pile 1.



2. Check that the piles are located where you expect them. If they are not, go to the Piles page and correct the incorrect data.
3. To print the pile layout:
   - right-click anywhere on the graph to display its context-sensitive popup menu and select **Print** from the popup menu
   - select **Print** from Repute's **File** menu

Step 6 - run the analysis

In Step 6, you run the analysis and view the results.

1. To run the analysis:
   - select **Run** from the **Build** menu (or)
   - click on the **Run the analysis** button on the Toolbar
2. To view the results:
   - From the **Reports** menu, select **Summary**.
   - From the **Summary** menu, select **Key Results**.

- click on the **Run the analysis** button on the Toolbar

3. If you wish to save your work, select **Save Project** from the **File** menu, choose where to save the project and what to call it, and click the **Save** button. Repute automatically adds ".rpx" to the filename you specify.
4. Exit Repute by selecting **Exit** from the **File** menu.

What next?

You will find further information about Repute, including example projects, in the program's help file, which you can open from Repute's **Help** menu.

Chapter 7
Background theory and assumptions

Repute's calculation engine is the leading-edge program PGroupN (used under exclusive licence from Geomarc), which provides a complete 3D non-linear boundary element solution of the soil continuum. This overcomes limitations of traditional interaction-factor methods and gives more realistic predictions of deformations and the load distribution between piles.

The PGroupN program is based on a complete boundary element formulation, extending an idea first proposed by Butterfield & Banerjee (1971). The method employs a substructuring technique in which the piles and the surrounding soil are considered separately and then compatibility and equilibrium conditions are imposed at the interface. Given unit boundary conditions, i.e. pile group loads and moments, these equations are solved, thereby leading to the distribution of stresses, loads and moments in the piles for any loading condition.

A full description of the theory behind PGroupN is given in the *Repute Reference Manual*, which is provided in electronic form with the program. What follows in this chapter is a brief summary of the boundary element method and the way it is implemented in PGroupN.

The boundary element method

In the boundary element method (BEM), the characteristics of the soil response are ascribed to the pile-soil interface elements. This approach requires discretisation of the pile-soil interface only, with enormous savings in computational time and data preparation effort.

In the boundary element method, remarkably few elements are required to achieve accuracy of results. A typical BEM mesh for a single pile is shown below, involving discretization of the pile-soil interface into a number of cylindrical elements. The behaviour of each element is considered at one node which is located at the mid-height of the element. This, in practice, reduces the dimensionality of the problem by one and makes 3D modelling a realistic proposition, even for large pile groups.

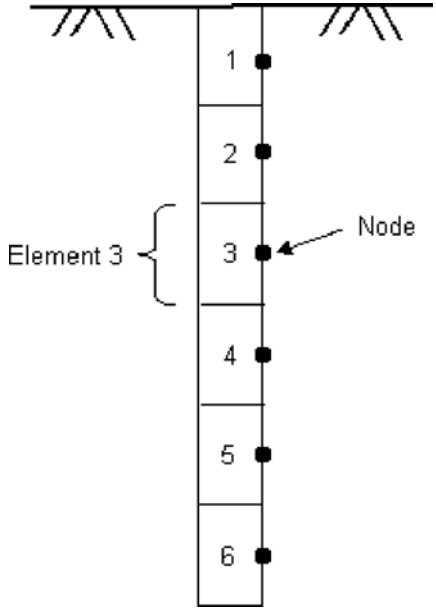


Figure 1. Typical boundary element mesh for a single pile

PGroupN method of analysis

The main feature of the PGroupN program (Basile, 1999, 2003) is its capability to provide a complete 3D non-linear BEM solution of the soil continuum while retaining a computationally efficient code.

Following the typical BEM scheme, the PGroupN analysis adopts a substructuring technique in which the piles and the surrounding soil are modelled separately and then compatibility and equilibrium conditions at the pile-soil interface are imposed. The soil is modelled using the well-established solution of Mindlin (1936), while the piles are modelled using the classical Bernoulli-Euler beam theory. Thus, given unit boundary conditions, the pile and soil equations are combined together and solved, thereby leading to the distribution of stresses, loads and moments in the piles for any loading condition.

The external group loads are applied incrementally and, at each increment, a check is made that the stress state at the pile-soil interface does not violate the yield criteria. This is achieved by specifying the limiting stresses for the soil according to the classical equations for the axial and lateral pile shaft capacity, and end-bearing resistance. The elements of the pile-soil interface which have yielded can take no additional load and any increase in load is therefore redistributed between the remaining elements until all elements have failed. Thus, by successive application of loading increments, the entire load-displacement relationship for the pile group is determined. Further details on the theoretical formulation

of PGroupN are given in Basile (2003).

Choice of soil parameters

The choice of soil parameters for PGroupN is simple and direct: for a linear analysis, it is only necessary to define two soil parameters whose physical interpretation is clear, i.e. the soil modulus (E_s) and the Poisson's ratio (νs). If the effects of soil non-linearity are considered, the strength properties of the soil need also to be specified, i.e. the undrained shear strength (C_u) for cohesive soils and the angle of friction (ϕ') for cohesionless soils. Thus, the proposed method, by taking into account the continuous nature of pile-soil interaction, removes the uncertainty of empirical t-z and p-y approaches and provides a simple design tool based on conventional soil parameters.

Non-linear soil model

The PGroupN analysis adopts a non-linear soil model, which follows the well-established hyperbolic relationship between soil stress and strain proposed by Duncan & Chang (1970) and also applied to pile problems by Poulos (1989) and Randolph (1994). This simple relationship assumes that the soil Young's modulus (E_{tan}) varies with the stress level at the pile-soil interface, i.e. it is a function of the initial tangent soil modulus (E_i), the hyperbolic curve-fitting constant (R_f), the current pile-soil stress (t) and the limiting value of pile-soil stress (t_{lim}), as shown in Figure 2. The hyperbolic curve fitting constant R_f defines the degree of non-linearity of the stress-strain response and can range between zero (an elastic-perfectly plastic response) and one (an asymptotic hyperbolic response in which the limiting pile-soil stress is never reached). The best way to determine the value of R_f is by fitting the PGroupN load-deformation curve with the data from the full-scale pile load test. In the absence of any test data, the value of R_f can be initially estimated based on experience.

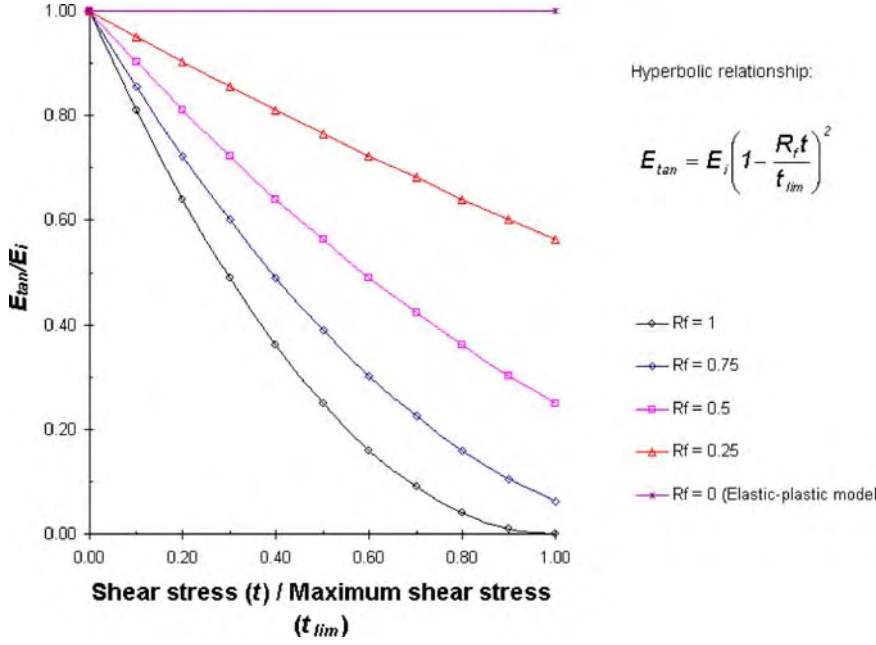


Figure 2. Soil Young's modulus variation with stress level

Figure 3 shows a typical example of how the non-linear soil model of PGroupN leads to a more realistic predictions of pile response and a better fit with the observed behaviour than traditional linear elastic or elastic-plastic models.

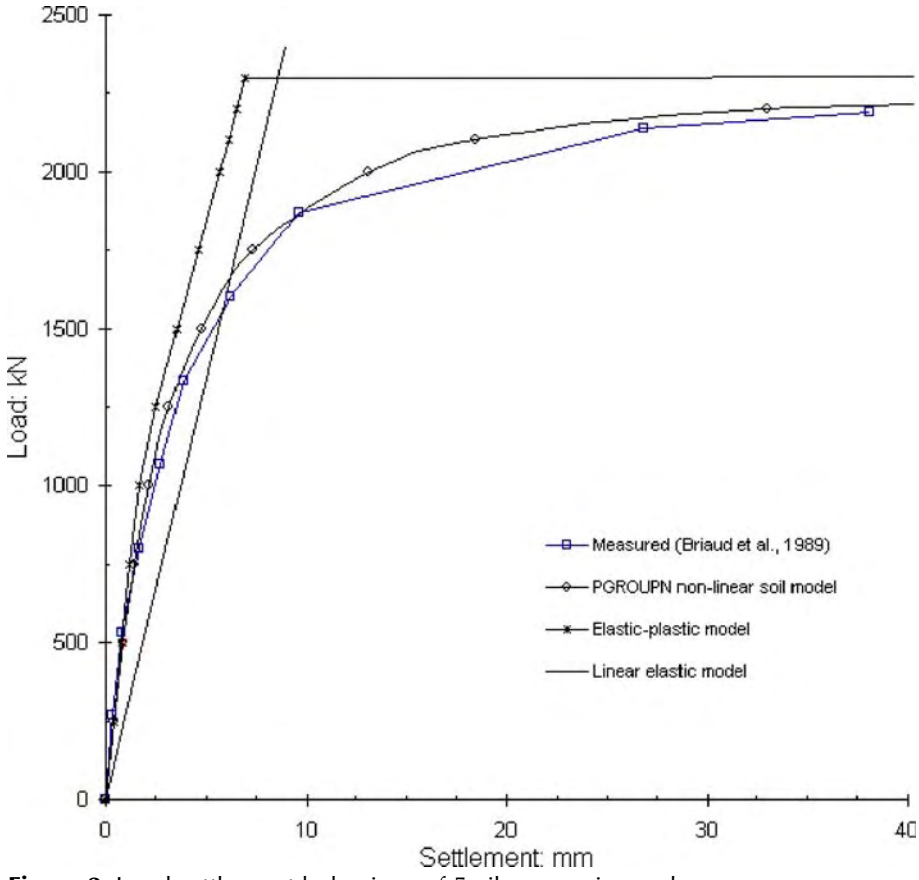


Figure 3. Load-settlement behaviour of 5-pile group in sand

Another fundamental limitation of the linear elastic models is that they result in a considerable overestimation of the load concentration at the outer piles of the group, and this may lead to an overconservative design. Indeed, it has long been recognised that consideration of soil non-linearity results in a relative reduction of the load concentration at the corner piles and a more uniform load distribution between the piles. It has been shown that, even at typical working load levels, this reduction is significant. This aspect is therefore of basic importance in pile group design (which is strongly influenced by the high corner loads and moments predicted by linear elastic models) and offers the prospect of more effective design techniques and significant savings in construction costs.

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